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# Lingual Force on the Goshgarian Palatal Bar

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LINGUAL FORCE ON THE  
GOSHGARIAN PALATAL BAR

by

Dennis J. Lazzara, D.D.S.

A Thesis Submitted to the Faculty of the Graduate School  
of Loyola University in Partial Fulfillment of  
the Requirements for the Degree of  
Master of Science

June

1976

DEDICATION

to my wife Nancy

For her love, devotion, and patience

## ACKNOWLEDGEMENTS

My sincere appreciation is extended to all those who have aided in making this investigation possible. I would like to extend a special thank you to the following persons:

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To John Hall, M.S., Director of Strain Gauge Department, Magnaflux Corporation, and his assistant, Evelyn Leydig, for their technical advice in the formation, design, and fabrication of this appliance and for their

many hours of patience in teaching this student.

The most profound gratitude I can express goes to my parents, for offering the greatest support and encouragement through my first twenty-eight years of life and making me what I am.

## AUTOBIOGRAPHY

Dennis J. Lazzara was born on March 14, 1948 in Chicago, Illinois, the son of Joseph and Jacqueline Lazzara. He was the first of three children, having two sisters Darlene and Deborah. In 1956, his family moved to Elmwood Park, Illinois. He was graduated from Fenwick High School in 1966 and began attendance at St. Procopius College in Lisle, Illinois. After two years, he transferred to the University of Dayton, Dayton, Ohio, where a Bachelor of Science degree was received in 1970. In the fall he matriculated at Loyola University School of Dentistry. In December of 1971, the author was married to Nancy Ann Pirhofer. A degree of Doctor of Dental Surgery was received in June, 1974 and the following July, he enrolled at the Graduate School of Orthodontics, Loyola University, School of Dentistry, and in the Postgraduate program in Oral Biology.

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## CHAPTER I

### INTRODUCTION

The purpose of this study was to determine the lingual forces exerted by the tongue on an orthodontic appliance. The appliance utilized in this study was a Goshgarian palatal bar.

An orthodontist's concern of tongue activity falls within the realm of the force applied to the dentoalveolar complex and the resultant effect on occlusion. Recognition that tongue activity can affect orofacial imbalances dates back as early as the 1870's. This realization in the 1920's encouraged researchers to quantitate tongue function.

It is known that a range of tongue activity and adaptability exists to reasonable alterations in the dento-facial complex. The challenge to determine which malocclusions were environmentally related became a paramount concern to the direction of orthodontic therapy. The inherent ability of the tongue to accommodate to various types and directions of treatment needed to be elucidated.

Measurements of tongue force were recorded electro-dynamographically. These procedures were carried out on high-angle subjects immediately after placement of the appliance and seven days later. It was felt this was

adequate accommodation time.

## REVIEW OF THE LITERATURE

### I. HISTORY OF ELECTRONIC MEASURING DEVICES

Orthodontists, as early as the beginning years of the twentieth century, were interested in the effects of various oral habits and muscle activity on the dentition. One of the main concerns was related to the force exerted on the dentition and its effect on tooth position by lip and tongue function. Therefore, encouraged by early research that muscle activity can affect occlusion, researchers attempted to quantitate this muscular force.

Basically, two different devices have been developed and tested for recording muscle pressure. In the first device, the pressure was mechanically transmitted through a closed channel to a manometer system extraorally. In the other system, the intraoral pressures were first converted to electrical signals which were then transmitted for amplification and recording outside the mouth.

With the introduction of new electronic measuring techniques, methods of measuring intraoral muscle activity became possible in 1948. Until this time, electrodynamic quantification of normal functional intraoral pressure had been limited by the sophistication of measuring devices. An example was the work in the mid 1920's of Stetson<sup>1</sup> who used small balloons as pressure sensors within

the mouth and a pneumatic-mechanical linkage to record pressure waves on smoked kymograph drums. Howell and Manley<sup>2</sup> were the first to adapt an electronic strain gauge technique in their investigation of maximum biting forces.

Alderisio and Lahr<sup>3</sup> in 1953 applied the resistance strain gauge as a measuring device in their presentation of the dynamics of intraoral muscle activity. Numerical values were not reported since these researchers were only interested in a graphic presentation of the dynamics of these pressures.

in 1954 Margolis and Prakash<sup>4</sup> utilizing the manometer approach added a photoelectric system and recorded the pressures continually through the use of an electromagnetic pen. They called this device a photoelectric myodynagraph.

Utilizing the (SR4) strain gauge, Winders<sup>5</sup> attempted to establish a reliable method of measuring forces exerted on the dentition by the perioral and lingual musculature. He measured oral pressure in five areas of the dentition at rest and also while the patients performed four functional swallowing exercises. The development of a strain gauge carrier and mode of attachment of the gauge to the carrier resulted in the success of this experiment.

Abrams<sup>6</sup> mounted electronic measuring devices on a thin vinyl plastic sheet adapted to a model and measured the forces exerted on the palate. With this technique, he could measure six different areas simultaneously.

According to Proffit<sup>7</sup> only recently, perhaps since 1963, has the instrumentation itself reached a satisfactory stage of reliability and accuracy. The result of the development of high-quality electronic amplification systems which can handle the small signals from miniature intraoral pressure transducers will permit a more complete understanding of tongue pressure capabilities and its effect on the dentition. Also, extremely small foil gauges have replaced the bulkier wire strain gauges of earlier days.

At the University of Kentucky, pressure transducers have been designed to be mounted in a thin plastic carrier with only the pellet at the end of the cantilever beam exposed to the pressure of the tongue or lips. Thin metallic housings are also available for direct attachment of the strain gauges to teeth, archwires, etc.

Wallen<sup>8</sup>, an orthodontic resident at the University of Kentucky, developed a variable angle transducer to measure the direction as well as duration and magnitude of tongue pressures. He compared anterior lingual pressures in a variety of planes of space. In so doing a study of vertically as well as horizontally directed forces against the dentition assisted in a more thorough description of oral activity.

More recent technical developments have been concerned with computer assistance in analysis of pressures,

duration of contact, time-pressure integral, and time relationships between pressure curves at multiple recording locations. Computed data can also be stored for accurate calculations and referrals.

The most recent technical step has involved the development of a portable system for pressure recordings outside the laboratory.

On field studies, special portable amplifiers and small data tape recorders are now available.

Proffit utilized this equipment in 1972 to obtain labial-lingual pressure recordings on members of the Walbiri aborigines in central Australia.

#### B. Swallowing

Straub<sup>9</sup> described normal deglutition thusly, "Individuals whose teeth are in good or fairly close to normal occlusions close their teeth firmly in centric as the first step. The next action is the depression of the tip of the tongue and then placing the tongue in the palate well back in the mouth with the tip placed at the posterior part of the rugae. The tongue pressure is exerted backward and upward, the top of the tongue in position and moving slightly distally."

The classic three stages of swallowing were summarized by Straub as: Stage 1, the voluntary and conscious stage when the food is gathered to the isthmus of the fauces.

Stage II is the involuntary and at the same time conscious reflex mechanism. In this stage, the bolus passes through the oral and laryngeal portions of the pharynx. Stage III is both involuntary and unconscious as the bolus passes through the esophagus and into the stomach. The swallowing of the bolus then, is accomplished by negative pressure built up by the muscular function.

The automatic muscle movement of normal swallowing was described by Guyton<sup>10</sup> in a stepwise fashion:

1. The soft palate is pulled upward to close the posterior part of the nose from the mouth.
2. Vocal cords and larynx close strongly, and the epiglottis swings backward to prevent food from going into the trachea.
3. The sphincter which normally closes the esophagus relaxes, and the larynx immediately pulls upward to open the esophagus.
4. The pharyngeal muscles then constrict and force the bolus from the pharynx into the esophagus.

Cleall<sup>11</sup> used cinefluorographic tracings of a randomized group of subjects to describe four stages of swallowing. The first stage was the "rest position" from which the tongue and hyoid moved. The second stage occurred when the tongue tip moved forward from rest to establish contact with the upper incisors or palatal mucosa. The



third stage involved the dorsum of the tongue rolling back and reaching the junction of the hard and soft palates. The fourth stage occurred when the hyoid was in its most superior and forward position. Finally, the last stage was the "rest position" at the end of swallowing.

The swallowing center of the nervous system is located in the medulla oblongata and stimulus is transmitted to this center via the trigeminal nerve from the posterior part of the oral cavity. When this center has been activated, the series of muscular activities is initiated and usually cannot be interrupted.

The motor stimulus is transmitted via the glossopharyngeal and vagus nerves to the pharyngeal and laryngeal regions to move the bolus of food into the esophagus. The motor function of the intrinsic muscles of the tongue, as well as the genioglossus, styloglossus, and hyoglossus muscles is controlled by the twelfth cranial nerve (hypoglossal nerve).

The entire pharyngeal state according to Guyton<sup>10</sup> takes one to two seconds; yet this stage of swallowing will interrupt respiration for a one to two second period. Because movements in swallowing are too rapid for the eye to perceive, high speed cinefluorography using 30-60 frames per second is the only means of visualizing this movement.

### C. Studies on Intraoral Forces of the Tongue

An understanding of the effects of the enveloping musculature upon the development and coordination of the dental arches into which the individual units of the dentition conform is of great importance both in clinical orthodontics and in the study of growth and development. However, the quantitative measure of the environmental forces imposed by the surrounding tissues on tooth movement is extremely difficult. A controlled study of a natural environment is especially arduous since it has the liability of genetic mismatching, ecologic imbalances, and perverted patterns of neuromuscular activity.

The earliest suggestion of a balance of forces between lingual and perioral musculature and tooth position was proposed in 1873 by Tomes<sup>12</sup>.

Brodie<sup>13</sup> and Moyers<sup>14</sup> suggested time should also be considered a contributor to the equilibrium picture. They believed that the teeth, once they emerge from their bony crypts, are completely at the mercy of their muscular environment so far as their buccolingual and labiolingual positions are concerned. Their arrangement will be determined by the equilibrium between the tongue on the inside and the lips and cheeks without. "A change in muscular environment around a tooth will cause the tooth to move through the bone until it is again in balance."

Studying the theory of equilibrium as it applies to the element of the dentition, Weinstein<sup>15</sup> concluded:

1. forces exerted on the crown of a tooth by the surrounding soft tissue may be sufficient to cause tooth movement;
2. each element of the dentition may have more than one position of stable equilibrium; and 3. different forces, even when they are of small magnitudes if applied under a considerable period of time can cause important changes in tooth position. Weinstein basically contends that the constancy of individual arch dimensions as related to time reinforced the tooth position muscle environment theory.

Scott<sup>16</sup> is in disagreement with the concept of the determination of the dental arches by the influence of the surrounding musculature. He believed this encompassing soft tissue adapts itself to the position of the teeth. His theory is based upon fetal observations. Brodie<sup>13</sup>, re-emphasized this point as he disagreed with the inviolability of the original arch dimensions, suggesting that muscle pattern at one age is no indication of what the muscle pattern will be at a later age.

The question remains viable today, does perioral and lingual musculature have an effect on the position of the teeth? If it does, to what degree does it dominate the dentition and consequently govern orthodontic results?

Probably the greatest proponent of the effect of

adverse oral habits is Straub<sup>17</sup>. Unequivocally, he states that the abnormal swallowing habit is definitely one of the causes of some of our severe Class III malocclusions. Abnormal swallowing causes a complete collapse of the maxilla, and adverse growth of the mandible is caused by the masticatory pressure of a complete cross-bite on the upper jaw. Also the tongue is usually enlarged as a result of the position in which it is placed in abnormal swallowing. He reported that the importance of the tongue is emphasized if one considers that a person swallows twice a minute while he is awake and once a minute while he is asleep. An indication of a perverted swallowing habit exists when the muscles of facial expression appear to be active. Cleall<sup>11</sup> reported that adolescents with severe tongue thrusts on swallowing displayed jerky and inconsistent movement of the oropharyngeal complex.

Several other investigators, such as Ricketts<sup>18</sup>, Harvold<sup>19</sup>, and Brasch<sup>20</sup> feel the soft tissues and particularly the tongue play the most important role in dental arch morphology.

Attempts to quantify perioral and lingual pressures are noteworthy and the conclusions deduced are extremely interesting considering some of the early theories.

Kydd<sup>21</sup>, evaluating maximum forces exerted on the dentition found the greatest pressure of 8.05 pounds per

square inch or 5.623 grams per square centimeter to be exerted on the lingual aspect of the upper incisors and the least pressure, 1.3 pounds per square inch, was exerted by the tongue against the lower first and second molar position; lip pressures were 4.4 pounds per square inch. He concluded: 1. as Weinstein, that the lip and tongue were capable of moving teeth, 2. that the hypothesis of equilibrium between lingual and buccal pressures was not substantiated, and 3. that other balancing forces were thought to exist.

As was reported earlier, Winders<sup>5</sup> using strain gauges and a series of exercises found that the tongue could exhibit as high as 600 to 800 grams of pressure on the lingual surfaces of the lower anterior teeth, as compared to less than 200 grams of pressure by cheek musculature. His conclusions suggested: 1. there appears to be more pressure exerted on the dentition by the tongue than by buccal musculature during speech and also during maximum effort, 2. the top of the tongue is capable of exerting the most force, with the side of the tongue, upper lip and cheek following in that order. Due to the imbalance of linguallly and buccally directed muscle forces acting on the dentition, Winders believed the position of the teeth are determined by the skeletal base. Despite the existing muscular imbalance, Winders believed an equil-

ilibrium exists within the dentition. The apparent imbalance could be equalized by considering the forces of occlusion, lingual inclination of teeth, design of roots, and their attachment to the alveolus.

Further investigations by Winders<sup>22</sup> concerning oral forces on the dentition during swallowing revealed no statistically significant correlation between swallowing forces and anteroposterior position of teeth.

The total effect, according to Subtleny<sup>23</sup>, of lingual forces on tissue form must be evaluated as a composite of: 1. frequency of force application, 2. duration of force, and 3. magnitude of force exerted. Estimates of the frequency of swallowing range from 1200 to 2800 per day as was postulated by Straub in 1956. Lear, Flanagan, and Moorrees<sup>24</sup>, reported a swallowing frequency of 585 times per day with a range of 203 to 1008. An appreciably lower incidence of swallowing than was suggested by earlier estimates.

Earlier research conducted by Lear, et. al.,<sup>25</sup> was concerned with buccal and lingual force measurement utilizing strain gauges. They found the average force exerted during deglutition to be 6.9 grams on the palatal surface of the premolars for approximately two seconds. Using a force gradient of 6.9 grams for 2 seconds and a frequency

of deglutition factor they stated that the force contribution during deglutition, if converted to continuous rather than intermittent function, is only  $1/40 - 1/20$  as great as the resting forces. Subtleny<sup>23</sup> compared this finding with the work of Kydd and Neff<sup>26</sup>. He indicated the total energy in tongue thrusting incident to the dental arches may approximate subjects with no "so-called" anomalies of tongue function. He summarized, "regardless of the pattern of tongue activity during swallowing, the deglutitive act may play a minor role in whatever influence soft tissue function has upon hard tissue form."

Utilizing strain gauge pressure transducers, Proffit<sup>27</sup> determined peak lingual pressures during swallowing in children ranged from 50-100 grams per square centimeter similar to that seen in adults. He also related each individual tended to reproduce his own pressure levels and the pattern of swallow activity was consistent for each individual. Concerning lingual pressure and arch form, Proffit maintained tongue activity during swallowing is not strongly related to maxillary width. The factor which appears to control arch width operates independently of lingual pressures, i.e. narrow maxillas had high lingual pressure and low buccal pressure. Therefore, arches were not assuming harmonious balance and muscle

pressures.

McGlone and Proffit<sup>28</sup> pursued this hypothesis one step further by correlating functional lingual pressure and oral cavity size. They concluded that little relationship exists between the size of the oral cavity and the pressures exerted against it by the tongue during either speech utterances or swallowing. Apparently during both activities the tongue makes only as much contact with the teeth and alveolar ridge as necessary to perform the required activity. Functional activities contributed only to a limited extent to the overall growth of the oral cavity. Perhaps, the true situation is a "semi-functional" matrix; where functional activities contribute to the overall growth, but to a limited extent.

Cookson<sup>29</sup> recognized tongue activity was as much a part of orthodontic diagnosis as is the assessment of the rest of the soft tissue morphology evaluated tongue resting position. He concluded there existed no significant correlation between tongue position and either skeletal or occlusal Class III cases, and secondly, with the incidence of cross bite in these cases. The lack of correlation of these findings would seem to confirm that environment and the afferent stimuli from the environment dictate tongue position.

Recognizing that palatal vault morphology and



palatal pressures differ, Kydd<sup>30</sup> measured the magnitude of lingual pressures in three areas utilizing a Hawley type of retainer. In this study during the exercise of swallowing saliva, the lingual pressures exerted on the hard palate ranged from 37 to 240 grams per square centimeter. The lingual pressures tended to be highest on the dentition, intermediate on the lateral and anterior palatal areas and lowest at the center of the hard palate.

After measurement on a sample size of 15 subjects, he concluded:

1. Palatal morphology of the subjects had an influence on the relative swallowing pressures exerted by the lingual musculature on the hard palate.
2. A large range of variation was found in the magnitude of mean swallowing pressures with the different swallowing activities.
3. The magnitude of pressures during swallowing of saliva on command was approximately twice that of spontaneous swallowing without command.

Most, if not all of the literature previously cited concerning the equilibrium theory relates to the horizontal positions of the teeth in the arches. Vertical position according to Proffit<sup>28</sup> may well be influenced by

functional activity. Vertically-directed intermittent forces accompanying swallowing and other activities might well influence the amount of eruption. The mechanism of tooth eruption is poorly understood, however, it is known that the eruptive force is only a few grams. In his summary, Proffit stated the influence of the tongue on the vertical position of teeth seems likely from clinical observations. However, there is little information as to the importance of resting pressures versus those generated during swallowing.

## CHAPTER III

### MATERIALS AND METHODS:

#### I. Selection of Subjects:

Selection of subjects was performed during the initial diagnosis of new patients which were scheduled to undergo active treatment in the orthodontic clinic. Eleven subjects were chosen; eight were male and three were female. The subjects ranged in age from 10 to 15. They were selected on the basis of a cranial base to mandibular plane angle measurement of 40 degrees or more.

#### II. General Procedures:

The specific question to be answered--what is the amount of force produced by the tongue and transmitted to the upper first permanent molars by the insertion of a Goshgarian palatal bar?

Therefore, an electronic device was designed and fabricated for reliable recordings of lingual forces exerted against the palatal bar. The Goshgarian palatal arch is a .036 dead soft transpalatal arch characterized by an integral U-shaped compression loop attached to a lingual sheath on the upper first permanent molar bands.

The object of the arch is to provide an adjustable removeable palatal wire which has the capacity to expand, rotate, contract, intrude, or torque a patient's upper first permanent molars.

The precision foil strain gauges, PA-06-015EE-120, were manufactured by Magnaflux Corporation in Chicago, Illinois. The dimensions of the miniature strain gauge were .015 x .015 inches. The gauges were chosen because of their adaptability to the palatal bar, cyclic reliability, accuracy for recording a large range of forces, and ease of calibration.

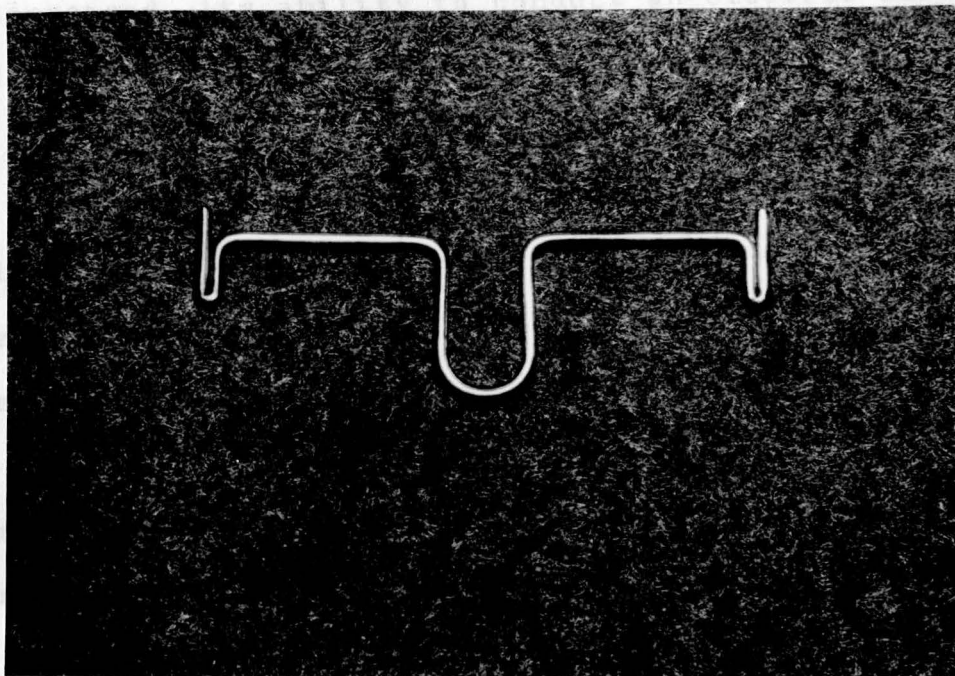
After selection, each subject was scheduled for individual appliance fabrication. At this appointment, maxillary first permanent molar bands were fitted and cemented; a Goshgarian palatal bar was selected. It was also passively adapted at this seating. For the purpose of consistency, each palatal bar was adapted according to intermolar width, and palatal vault morphology, utilizing the occlusal plane as a reference. Because the subjects were selected on the basis of their presenting a NS-GoGN angle of  $40^{\circ}$  or higher and an orthodontic appliance of this nature would be most beneficial in the control of vertical dimension, clinical observation was also employed in the placement of the transpalatal bar

relative to a position of optimum expectability. The adapted palatal bar was removed for attachment of the miniature strain gauges.

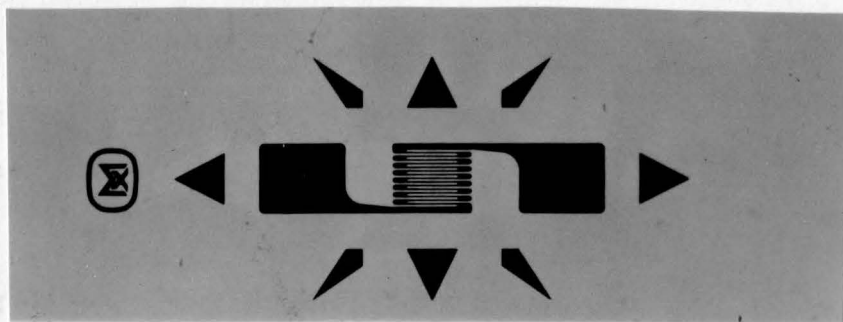
Four miniature strain gauges were attached to each bar at the point of insertion of the transpalatal bar into the lingual sheath on the molar bands. The gauges were mounted two at either end,  $180^{\circ}$  to each other and  $90^{\circ}$  to the vertical for recording the compression and tension imparted by tongue to the palatal bar.

Using a palatal bar from which intraoral measurements may be taken has certain advantages due to the nature of the metal: 1. the stress strain curve of metal is more reliable and linear by nature than other materials, and 2. the elastic properties are affected less by changing temperatures. The greatest strain occurs at a moment nearest the fixed or supported end, so the gauges were mounted as close to the attachment on the molar as possible. The strain on the palatal side of the palatal bar is termed tensile strain and the strain on the lingual surface compressive.

The usual form of the strain gauge consists of resistance wire wound back and forth in the form of a grid. The principle behind the mechanics of strain gauge technology is that if the cross section of a given wire



Goshgarian Palatal Bar



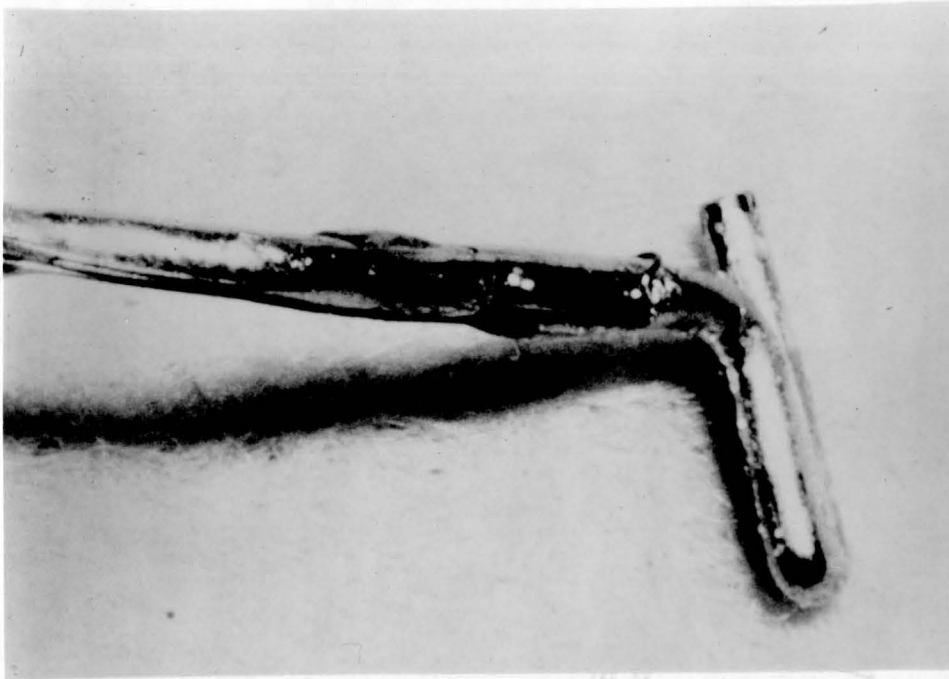
Magnaflux Strain Gauge PA-06-015EE-120

is decreased, its ability to conduct an electric current is decreased, or the resistance of the wire is increased. The gauges in this experiment were mounted to the palatal bar in such a manner that pressures exerted by the tongue would alter the form of the bar and therefore the character of the strain gauge. The fixed palatal bar then acted as a second-degree lever.

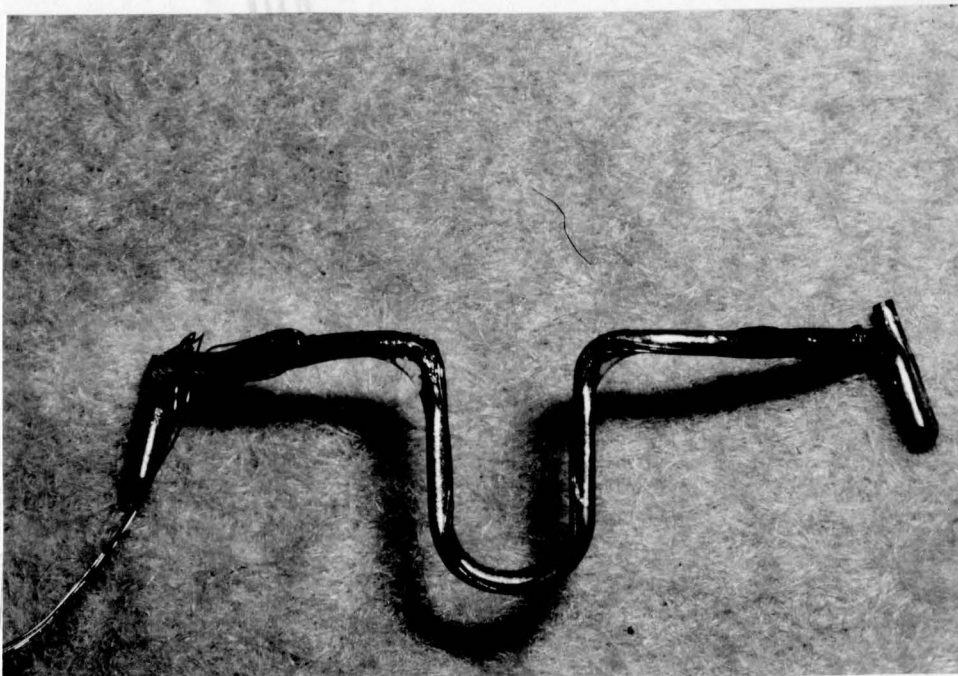
Each strain gauge was prepared under a dissecting microscope for attachment to the palatal arch wire by first removing all foil direction guides. Preparation for cementation was accomplished by means of cleansing of the reverse side of the strain gauge and the point of fixation on the palatal bar with a cotton swab and a neutralizer (an alcohol base), followed by a second swabbing with methyl ethyl ketone. The gauges were affixed to the palatal bar with BR610 adhesive (W. T. Bean Co.), cured for one hour at 350°F. During curing the gauges were held in place conforming to the curvature of the bar by means of teflon sheets and rubber clamps.

After curing, the excess adhesive was removed and the gauges wired into a wheatstone bridge circuit with #39 polyurethane insulated magnet wire.

After the appliance was wired, the patency of the circuit and the resistance of the bridge was determined. The final step in the fabrication of the appliance con-

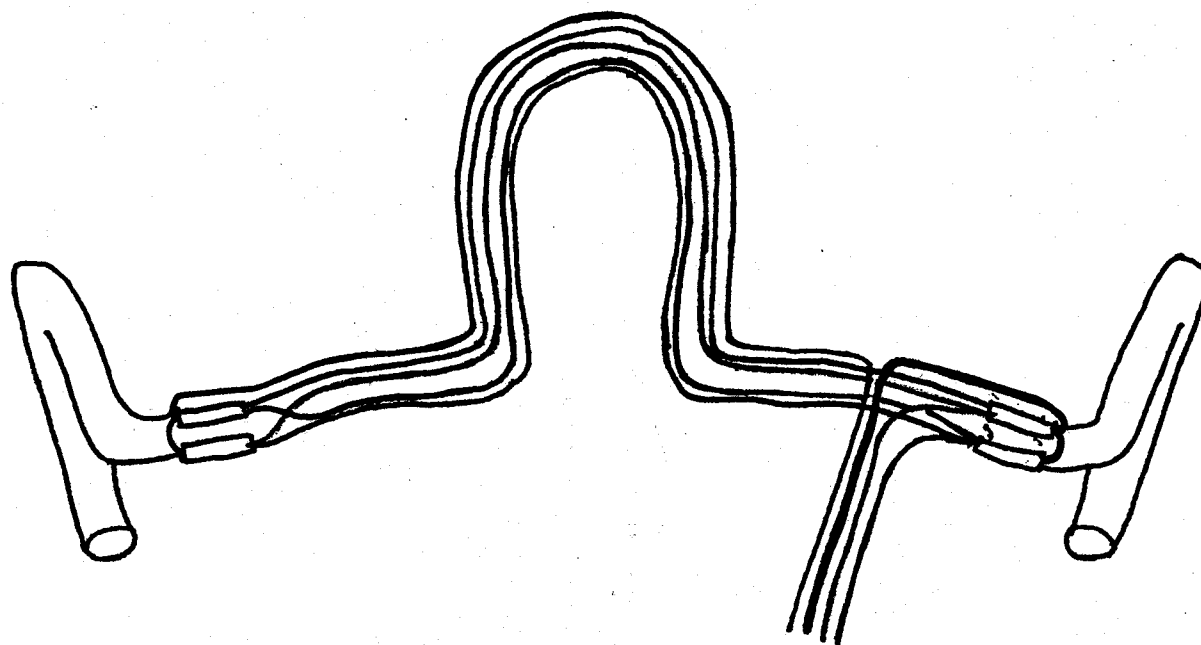
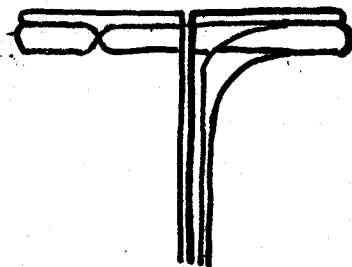


Strain Gauge Mounted and Wire  
Soldered on Palatal Bar



Sealed Palatal Bar with Strain Gauges  
Mounted and Lead Wired Attached





AM

Illustration of Palatal Bar with Strain Gauges Mounted and Representative Wiring

cerned the sealing of the gauges and wiring from the oral fluids, which might corrode the gauges and/or dissolve the adhesive. This was accomplished by coating the bar with Nuva-sealant and curing it with ultraviolet light.

### III. Tongue Pressure Recordings

Before the myometric tongue recordings could be measured, the order of the wiring of the strain gauges in the Wheatstone bridge configuration had to be determined, i.e., it was necessary to confirm which of the four leads were paired--two being excitation and two being signal. This confirmation was important because an external known resistance had to be introduced between an excitation and signal lead. The determination of leads was accomplished by means of a voltage-ohmmeter.

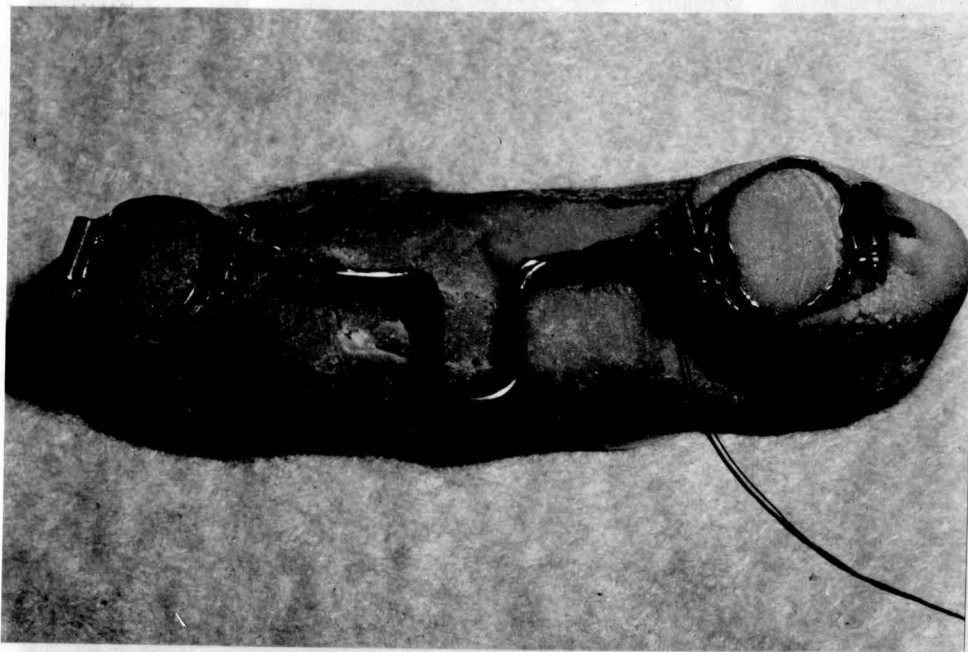
Analysis of the magnitude of resistance introduced was performed by mounting the completed appliance on a custom acrylic template of each subject's intermolar width, height, angulation, and torque. Controlled resistances were added until a 1 gram weight imparted an approximate one millimeter pen deflection. An AC-DC decade resistance box was employed for the introduction of this resistance because instrumentation would not supercede unusual offsets in the strain gauges.

The strain gauges were utilized as measuring devices, so a fully transistorized carrier preamplifier was needed. This preamplifier emitting 1.5 volts r.m.s. was also used for excitation of the bridge. The absence of capacitors in this preamplifier allowed for a dynamic and static picture of time related force recordings and not simply peak values.

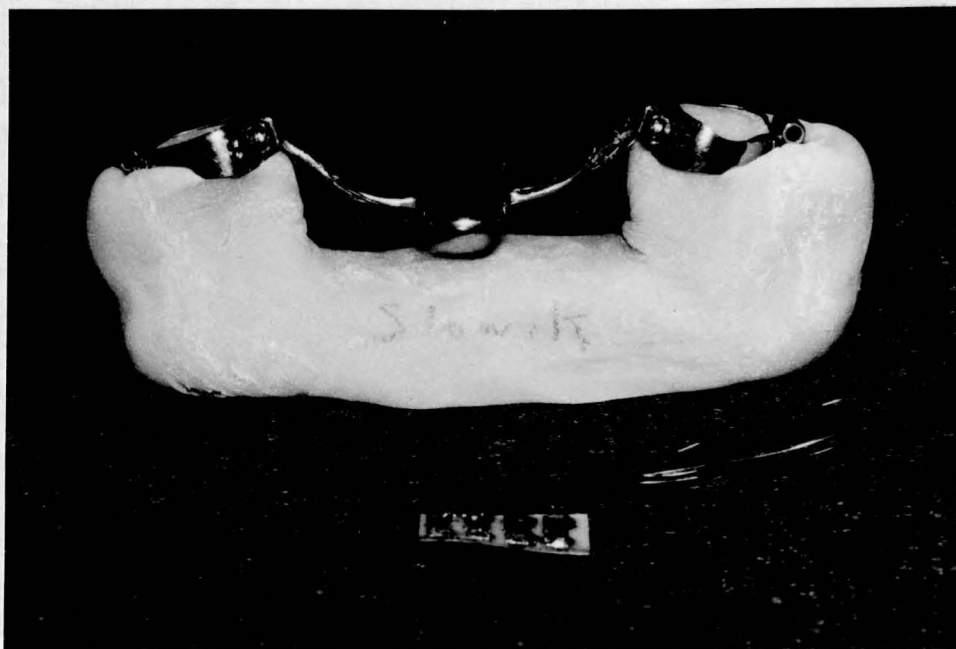
The recordings of the strain gauges were transferred from the carrier preamplifier manufactured by E & M Instrument Company, Inc., to a physiograph manufactured by Narco Instrument Company and were recorded on graph paper by means of a deflecting pen.

To convert the amplitude of pen deflection into its respective force value, the conventional weight loading method was used utilizing the standard 10, 20, 30, and 50 gram weights placed on the bar, after the bar had been removed from the patient's oral cavity and inserted into the custom acrylic template mentioned earlier. This procedure was performed after each recording.

Recording of tongue pressure was carried out in a frequency-controlled room. The subjects were seated in a dental chair and the four lead wires exiting the oral cavity via the buccal vestibule were soldered to a coupling for the carrier preamplifier.



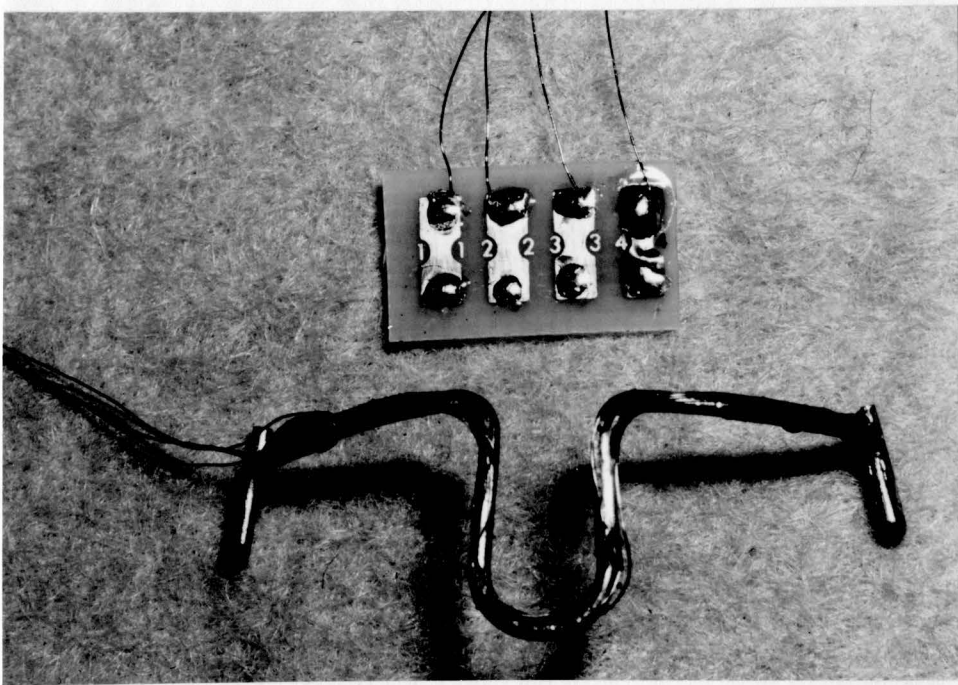
Appliance Inserted in Custom Template



Palatal Bar Completed with Lead Wires  
Soldered to Junction Plate



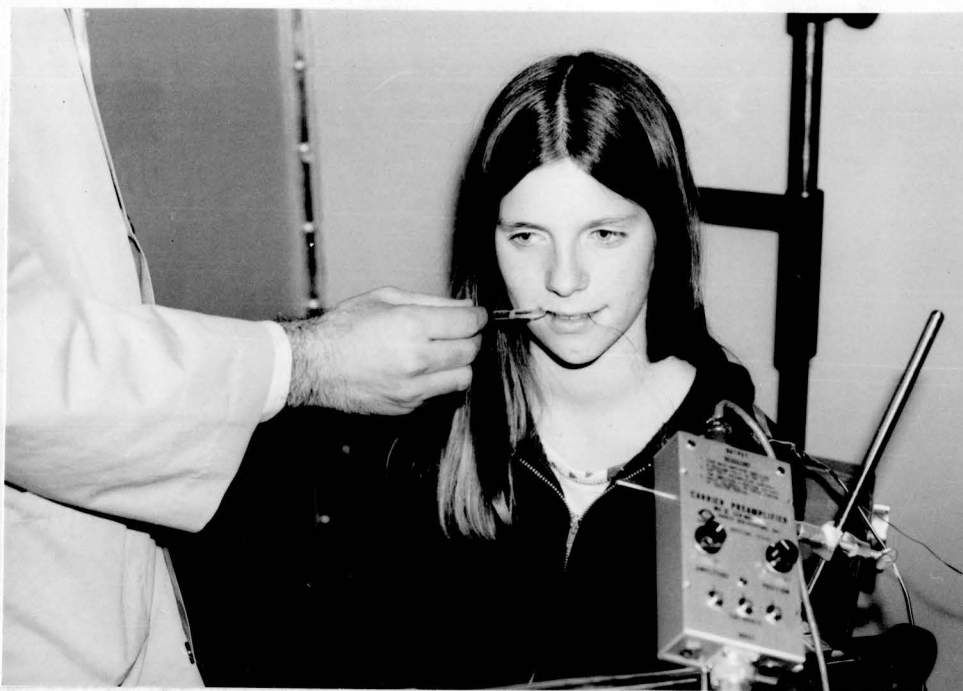
Appliance Placed in Subject



Palatal Bar Completed with Lead Wires  
Soldered to Junction Plate

In between swallows, water was added to the subjects' labial vestibules by means of an eye dropper. The added 2 cubic centimeters of moisture maintained a consistent volume of liquid for deglutition.

The subjects were allowed to swallow after placement of the liquid until approximately fifteen representative swallows were recorded. A mean peak value was determined for each recording. Two recordings were taken immediately after initial placement. Exactly one week later the entire procedure was reproduced.



The Introduction of Water During  
Recording of Tongue Forces



Recording Session in Frequency  
Controlled Room

## CHAPTER IV

### RESULTS

The results of the strain gauge force measurements recorded on the physiography are presented in Table I. Each subject is represented in the first column by initials. The second column presents the mean lingual force recordings during deglutition immediately after insertion of the appliance. Measurements recorded after 7 days of appliance placement are presented in column three.

The instruments were calibrated intraorally at the beginning of each recording without contact of the lingual musculature; this initial rest position recording then became the base line for determination of force values.

Columns two and three demonstrate the degree of adaptation of the subject over a period of seven days. As is noted from Table I, the first nine subjects illustrate adequate tongue accommodation to the placement of the palatal bar. The last two subjects depicted an increase in tongue force over the seven-day period.

Table II presents the range of lingual forces recorded after initial insertion of the appliance and following a seven-day accommodation period. The first

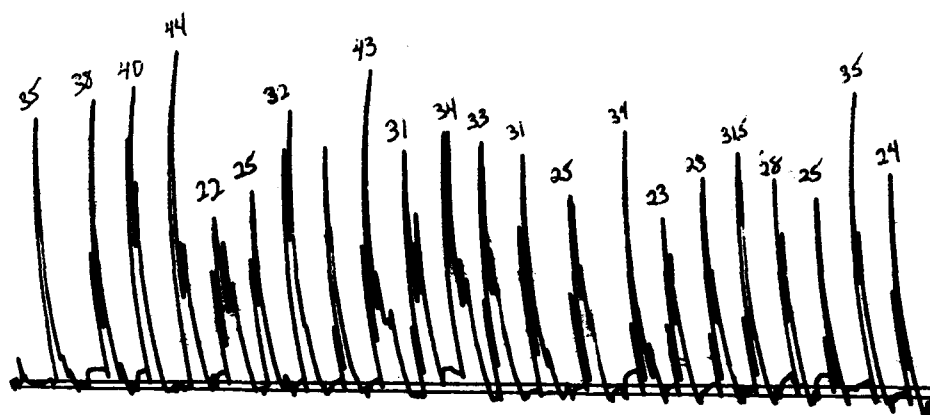


nine subjects again demonstrated a significant tongue accommodation. The last two subjects appeared to demonstrate a variable pattern of accommodation.

The range of lingual forces recorded after initial insertion of the appliance varied from 153 grams to 2050 grams; this demonstrated a mean force of 760.7 grams and a standard deviation of 320.05 grams. The measurements collected after a seven-day trial period ranged from 100 grams to 908.6 grams with a mean force value of 483.8 grams and a standard deviation of 166.16 grams.

A paired t-test was utilized to statistically analyze the results. The mean differences in tongue forces recorded initially and seven days later were statistically significant ( $.05 > p > .02$ ). After a seven-day period a significant pattern of tongue accommodation to the placement of a Goshgarian palatal bar was apparent.

A sample of the physiograph pen recordings are shown in Fig. (11).



Representative Recording on Physiograph

TABLE I

AVERAGE LINGUAL FORCE AGAINST GOSHGARIAN  
PALATAL BAR DURING SWALLOWING

(Grams)

<u>Subject</u>	<u>After Insertion of Appliance</u>	<u>Seven Days Following Insertion of Appliance</u>
1. PZ	773.00	666.10
2. JZ	787.00	472.20
3. DC	257.80	122.20
4. BB	495.00	247.00
5. RG	1072.50	596.70
6. RL	1080.00	585.80
7. DG	624.40	543.90
8. CD	1426.70	344.50
9. SD	829.20	573.10
10. JB	585.10	651.70
11. RS	437.00	518.30
- X	760.70	483.80
S.D.	320.05	166.165

TABLE II

RANGE OF LINGUAL FORCE AGAINST GOSHGARIAN  
PALATAL BAR DURING SWALLOWING

(Grams)

<u>Subject</u>	<u>After Insertion of Appliance</u>	<u>Seven Days Following Insertion</u>
1. PZ	420.0-1140.0	525.0-775.0
2. JZ	541.6-1083.0	311.1-611.1
3. DC	153.0-0357.0	100.0-138.9
4. BB	330.0-0660.0	162.5-350.0
5. RG	683.0-1167.0	533.3-716.0
6. RL	850.0-1312.5	512.5-725.0
7. DG	500.0-0933.3	409.0-704.5
8. CD	950.0-2050.0	239.2-457.1
9. SD	440.0-1140.0	360.0-908.6
10. JB	375.0-0783.3	516.7-733.3
11. RS	339.0-0593.0	316.7-783.3

## CHAPTER V

### DISCUSSION

This study was undertaken to determine the forces the tongue transmits to an orthodontic appliance. The appliance selected in this study was a Goshgarian palatal bar. It consists of a transpalatal bar often utilized in orthodontics to control vertical dimension in high-angle cases.

Specifically, this research project was interested in the magnitude of lingual forces vertically directed to the first permanent molars.

Difficulty was encountered in the instrumentation and calibration of this appliance. Inherent problems were:

1. Source of consistent excitation, AC or DC.
2. Amplification of output signal
3. Measurement of static and dynamic forces
4. Control of strain-gauge offsets

Circumvention of these problems was realized in the utilization of a carrier preamplifier. This instrument contributed pen position control, amplification control, bridge excitation, and measurement of static and dynamic

tongue function.

Difficulty was also encountered with the sealant's ability to protect the circuitry from the oral fluids. Seven days following the initial insertion of the appliance, the first three patients returned with the palatal bar completely denuded of the sealant and strain gauges. It appeared the sealant was unable to withstand the normal shearing and crushing action of normal mastication and deglutition. After initial insertion and recordings, the force sensitive palatal bar was removed and a duplicate passive bar was inserted minus the strain gauges and circuitry. The subjects wore this duplicate appliance for the seven-day accommodation period. The original palatal bar was inserted immediately before the final recording.

The precision or ability of each device to reproduce consistent measurements was evaluated extraorally by mounting the appliance in its custom template and measuring various loads. The results were accurate and linear not only in succession but at different recording sessions. The consistent cyclic pattern of the appliance was also deemed adequate due to the objective quality controlled intrinsic characteristics of each miniature strain gauge and the inherent repeatable stress-strain

nature of a metal bar. Accuracy of the intraoral recordings was attained in the consistency of each subject's swallowing pattern. This is exemplified by Proffit<sup>27</sup> who related each child has a distinctive and consistent pattern of pressure application.

He reported each child has a distinctive and consistent pattern of lingual force application. This consistency in each subject's swallowing pattern was noted at the initial recording session and also at the final recording. This author felt these findings fortify the accuracy and instrumentation of this appliance.

Although the appliance was capable of vector analysis and resultant forces due to the intrinsic nature of the strain gauge mounting and circuitry, this study concerned itself only with the determination of vertically-directed forces.

After the physiograph records were analyzed, the amplitudes computed, and the data (statistically) analyzed, it was determined that a statistically significant accommodation of the lingual musculature had taken place following insertion of a Goshgarian palatal bar for a period of seven days.

The purpose of introducing approximately two cubic centimeters of water after each swallow was to record a

more spontaneous type of swallowing pattern as to the voluntary swallowing which results from exercises performed on command. Kydd<sup>30</sup> stated only the mean pressures of drinking water came close to approximating those of spontaneous swallowing. He also found spontaneous swallowing was the lowest of all measurements taken as compared to the exercises of drinking water, sipping water, and swallowing saliva.

The subjects in this study were considerably different anatomically as well as physiologically in terms of palate morphology and deglutition. Anatomically, they presented normal, shallow and broad, and high and narrow palatal vaults. All subjects exhibited a "normal" swallowing pattern except for one. Subject J. B. demonstrated a very abnormal swallowing pattern, manifested by very labored deglutition, with a pronounced tongue thrust.

The important questions to be answered: does form determine function or does function determine form? Is there a cause and effect relationship?

Kydd<sup>30</sup> evaluated the effect of palatal morphology on measurements of swallowing pressures. He compared lingual pressures exerted in the center of the hard palate to lingual pressures in the lateral palate area. Subjects with round or average palates demonstrated lingual



pressures applied on the central area to be 64 percent of the pressure applied on the lateral palatal area. In subjects with peaked and narrow palates, this percentage decreased to about 40 percent. Flat palate subjects recorded an increased central area to lateral area percentage of 90%. Kydd concluded the palatal morphology of the subject had an influence on the relative swallowing pressures exerted by the lingual musculature on the hard palate.

Proffit<sup>28</sup> acknowledging this conclusion stated the true situation in the oral cavity is a "semi-functional" matrix, where functional activities contribute to overall growth but to a limited extent. If dynamic lingual pressures did contribute significantly to arch form, the tongue would closely fit the arch during these acts. Functionally, the intense forces of short duration are less related to form-function relationships than the longer but smaller resting forces. The lack of correlation between cavity size and swallowing forces may be interpreted to mean that determination of these functions is essentially lingual. That is, the neural control of the tongue musculature regulates the force that it exerts for each of these activities, and that control is dictated by the requirements necessary to complete the act.

In general, the results of this study support the form-function hypothesis. The form of the palatal vault was modified in each subject by insertion of a Goshgarian palatal bar. The significant accommodation to the alteration in anatomical structure was manifested by a reduction in lingual force after a period of seven days. This expected accommodation was evidenced in nine of the eleven subjects.

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Table I demonstrated an increase in tongue force of 66.6 grams over a seven-day period for subject J. B. This 11.3% increase in tongue pressure may best be explained biologically. This subject presented a very erratic labored swallowing pattern; the initial tongue thrust followed by a superior distal-displacing action of the dorsum of the tongue was once again followed by a tongue thrust. The myometric recordings illustrated a consistent triple peak swallowing pattern. "Normal" swallowing, according to Proffit<sup>31</sup>, exhibited a double-peaked curve. Coupled with this abnormal swallowing behavior, an awareness of the measuring device and procedure may also be responsible for a portion of the variability of the measurements.

It can be observed in Table I, that subject R. S. also did not accommodate to the alteration in palate

morphology. The average lingual force immediately after insertion was 437.1 grams and 518.3 grams after seven days. Subject R. S. presented with normal deglutition and average palatal vault morphology. This failure in accommodation may be interpreted as a lack of functional coordination or timing between the extrinsic and intrinsic muscles of the tongue, and as in subject J. B., the individual response to the afferent stimuli which dictate the neural control of tongue application and position is extremely difficult to assess.

Further explanation of subjects J. B. and R. S. may be gained by cineflouorographic analysis.

This author found the swallowing pattern reproducible for each subject utilizing this appliance and instrumentation. Each subject presented a consistent and definite double-peak swallowing cycle at each recording session, except for subject J. B. Proffit<sup>31</sup> felt this double-peak pattern is the most common in adult swallowing. Abrams<sup>6</sup> explained the activity of deglutition and its representative double peak as follows: "While the intrinsic muscles function in modifying the surface configuration of the tongue, the extrinsic muscles apply the upward thrust. With the force directed at the center of the tongue, the surface engages the palate in a rolling

contact up the vault toward the center of the palate. As the dorsum assumes a more convex shape, the rigidity of the tongue increases reaching maximum at full palatal engagement. This represents the first peak. After the food is expressed from the oral cavity, the tongue maintains its pressure on the entire surface of the palate. The second wave is seen in the pharyngeal stage of swallowing as the tongue is braced against the palate. Contact between tongue and palate is released abruptly at the termination of pharyngeal clearance with the exception of slight sluggishness in the posterior region of the tongue."

The significant level of accommodation evidenced in this study was expected. The ability to adjust to an alteration in palatal vault volume and morphology was determined after a period of seven days. This accommodation most likely occurred after a shorter period. This leads one to suspect the patient's proprioceptive feedback mechanism and neurologic control pattern to be ultimately important--an area poorly investigated and seemingly unique.

The clinical implications of the myometric results are extremely interesting if one compares the mean force values with earlier reported literature. Kydd<sup>30</sup> reported

the mean lingual pressures exerted on the hard palate during the exercise of drinking water, which most closely approximates that of spontaneous swallowing, to be 53 grams per square centimeter. The lingual pressures exerted during swallowing tend to be highest on the dentition, intermediate on the lateral and anterior areas, and least at the center of the palate. Winders<sup>22</sup> found the mean swallowing pressure applied lingually to the first permanent molar in his group of Class I excellent occlusions to be about 112 grams per square centimeter.

The mean lingual force of 760.7 grams recorded immediately after insertion of the appliance is indicative of an acute awareness to a foreign object, alteration in available palatal vault volume, and an infringement of tongue freedom.

The significant change in the mean force value after a period of seven days to 483.8 grams, a 37.4% decrease reflects the innate adaptive ability present in most individuals.

Brian Lee<sup>32</sup> attempted to translate prescribed pressures into biological determinates for directional tooth movement. He theorized a value of 200 grams per square centimeter of "en face" root surface was necessary for tooth movement. More recently, Ricketts<sup>33</sup> has

modified this value to a probable 150 grams per square centimeter for biologic efficiency.

The average "en face" root surface of a first permanent molar according to Brian Lee resisting an intrusive force is 0.80 square centimeters. A biologic efficiency of 150 grams per square centimeter then requires 120 grams of force to intrude a first molar. Clinically, the acceptance of visualizing the intrusion of the first permanent molars is more easily realized when one considers a force of 760 grams or 480 grams being exerted on the first permanent molars 600 times a day. An impression of palatal bar on the dorsal surface of the tongue is not difficult to accept considering a force range of 100 grams to 2050 grams.

Evaluation of the myometric recordings, also indicated the tongue to be in constant contact with the bar; the force value varied between 25 grams and 60 grams. This constant force would also lend credence to the intrusive capacity of the palatal bar.

A great deal of variance was found in the individual measurements of lingual forces exerted on this orthodontic appliance. An evaluation of the variables may possibly be answered on an individual basis. The size, shape, and action of the tongue correlated with palate morphology

would most likely account for some of this variance. Individual levels of awareness to the appliance and procedures would also account for variability in the recordings.

Lear and Moorrees<sup>34</sup> stated tooth movement can be affected clinically by mechanisms providing sustained force to the tooth crown. However, such circumstances do not parallel the much more complex and fluctuating constraints which are applied by the tongue and cheeks. Consequently there is a need to investigate the threshold levels and gradients of physiologic significance for force magnitude, force duration, and rate of force application and removal.

It is hoped the unanswered questions in this study will stimulate further investigation. A follow-up to this study could be performed by evaluating accommodation of subject exhibiting normal swallowing patterns and those presenting tongue thrusts utilizing the same techniques in this thesis. A time-pressure integral coupled with vector analysis may help to determine, according to Abrahms<sup>6</sup>, what reasonable changes of the dental configuration may well be within the adaptable range of the affected muscles.



## CHAPTER VI

### SUMMARY AND CONCLUSIONS

A technique was developed for measuring tongue forces against a Goshgarian palatal bar. An appliance was designed and fabricated for quantitatively recording the vertical lingual forces applied to this orthodontic appliance. Subjects presenting a high cranial base to mandibular plane angle were chosen for this study.

Eleven subjects (10-15 years old) were selected, all exhibiting a NSGoGn angle of  $40^{\circ}$  or more. An appliance was constructed, for each subject, to quantitate the force of the tongue. The following procedures were utilized:

1. First permanent molar bands were cemented and a Goshgarian palatal bar was formed.
2. Miniature foil-strain gauges were mounted on the palatal bar, wired in a Wheatstone bridge circuit, and sealed from the oral fluids with Nuva sealant.
3. The appliance was inserted and myometric measurements immediately recorded during an exercise of swallowing two cubic centimeters of water.
4. Seven days after the appliance was inserted, the

same procedures were followed.

5. The results were statistically analyzed and recorded.

An inflated force value was expected as a result of the decrease in available palatal vault volume and an accommodation to the insertion of the appliance was also assumed prior to placement. Both of these expectations proved to be true. The resultant force levels were fifteen times higher than the values reported by Kydd and seven times greater than those reported by Winders.

A statistically significant difference in the mean-force values had occurred after a seven-day period, denoting a neurologic accommodation.

Many questions remain unanswered and it is anticipated that further research will explore this area. It is generally accepted that the position of the dentoalveolar complex is a resultant interplay between inherited skeletal and neuromuscular components. This interaction has never been adequately defined. An alteration in this "equilibrium" between the hard and soft tissues would consequently cause a change in the dentoalveolar complex. The stability of every occlusion is dependent upon an understanding of these changes.

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### APPROVAL SHEET

The thesis submitted by Dennis J. Lazzara, D.D.S. has been read and approved by the following committee:

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The final copies have been examined by the director of the thesis and the signature which appears below verifies the fact that any necessary changes have been incorporated and that the thesis is now given final approval by the Committee with reference to content and form.

The thesis is therefore accepted in partial fulfillment of the requirements for the degree of Master of Science.

5/12/76  
Date

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Director's Signature